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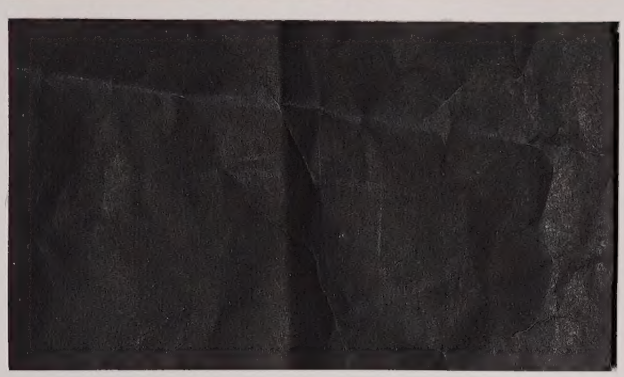

INSTRUCTION MANUAL

MP MASTER
MA32103

BARBER-COLMAN COMPANY
Industrial Instruments Div. • Rockford, Ill., U.S.A.

1211.8
IN 4-2

MODEL 277P

CAPACITROL

INTRODUCTION

This instruction manual is designed to help you secure maximum benefits from your new Model 277P Capacitrol. It should be given to persons responsible for installation, operation and maintenance of this instrument.

Your Barber-Colman factory trained field engineer is always available for further help in the solution of your control problems. Offices are located in all principal cities.

BARBER-COLMAN COMPANY
Industrial Instruments Division

Litho in U.S.A.

October 1966

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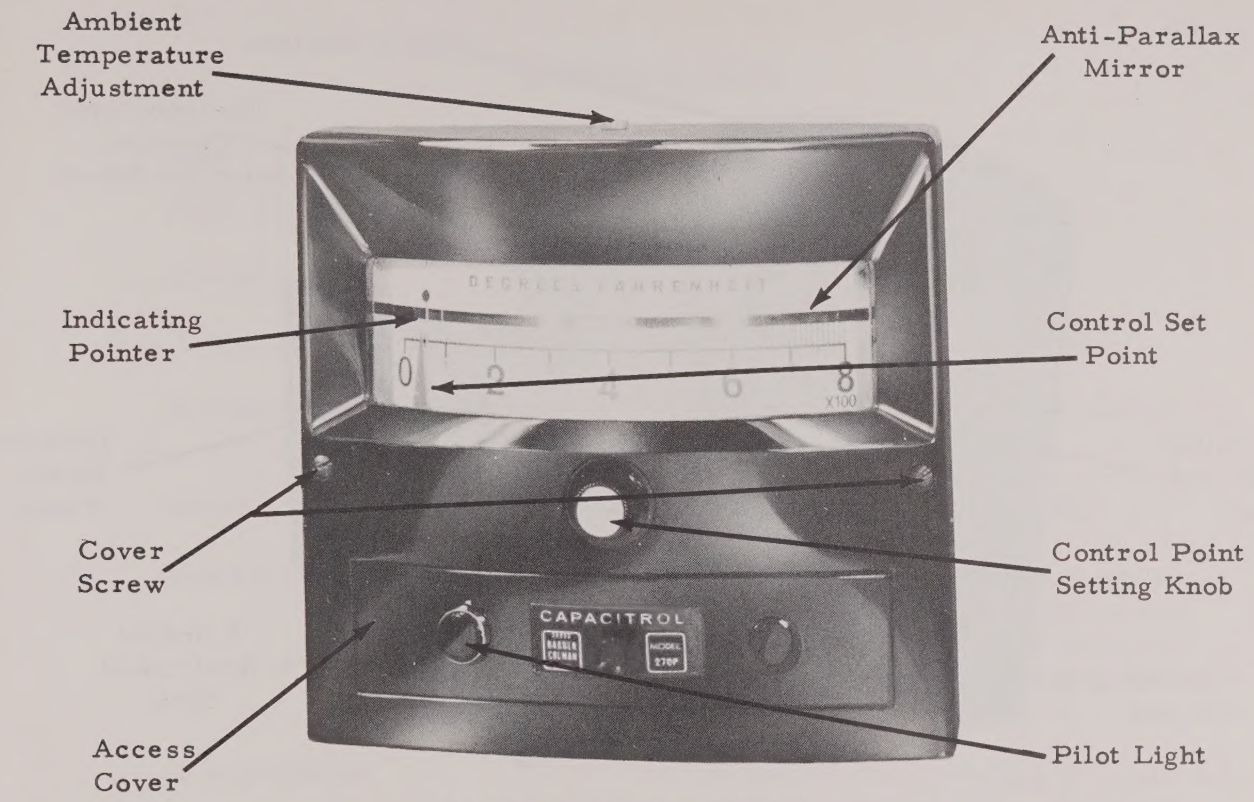
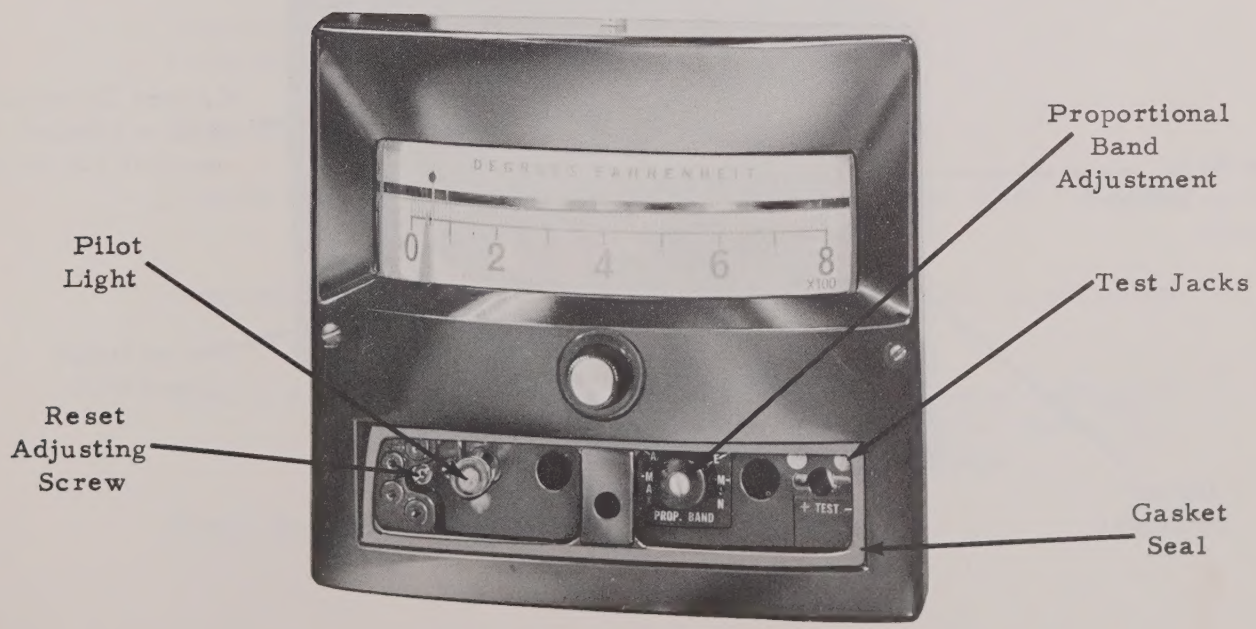
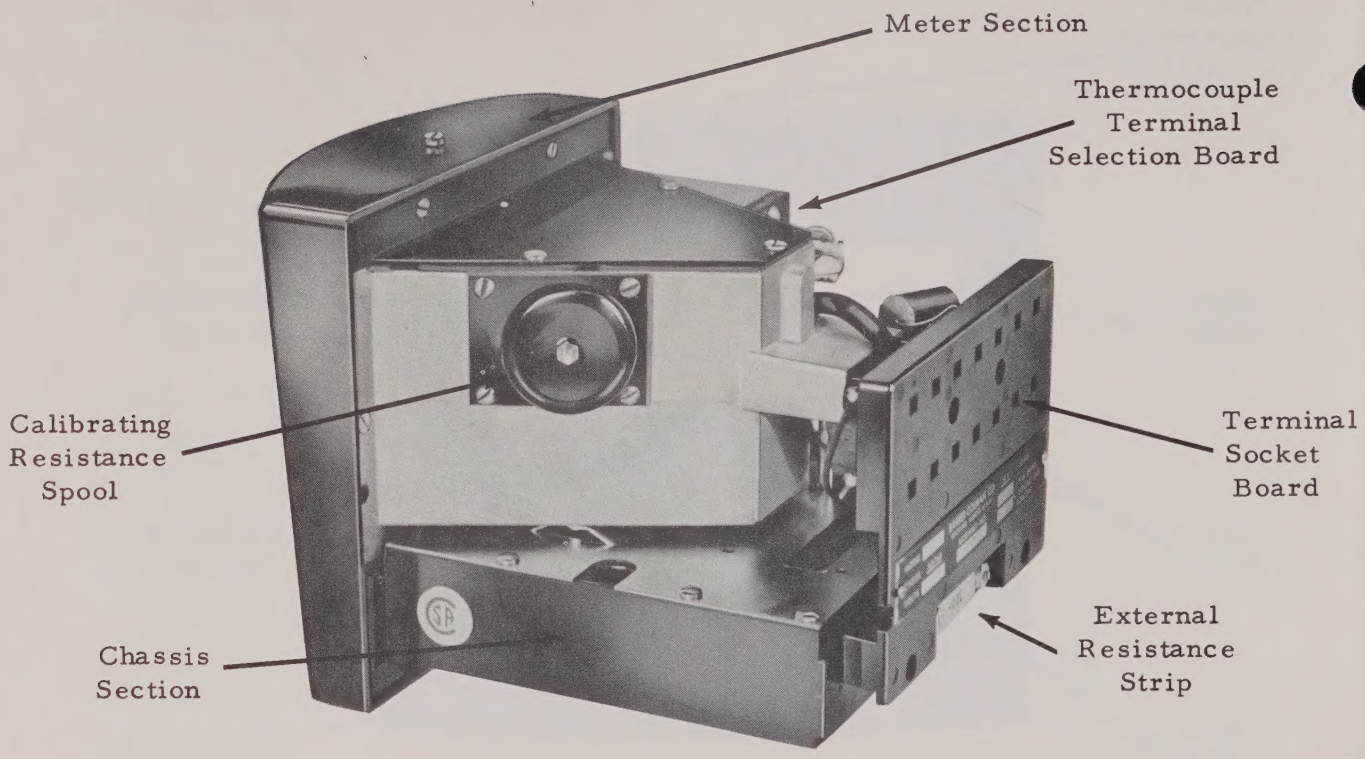


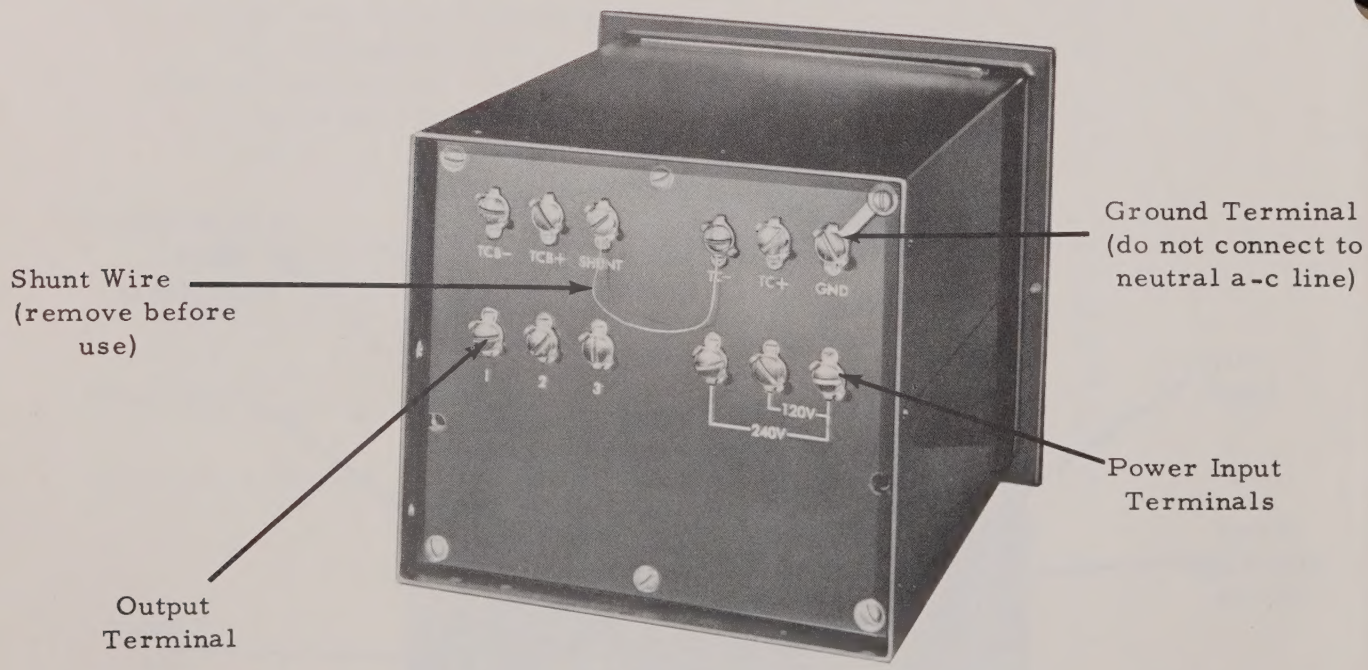
MODEL 277P CAPACITROL



FRONT VIEW - ACCESS COVER REMOVED



METER-CHASSIS UNIT



REAR VIEW OF HOUSING

SPECIFICATIONS

Meter

Scale Length	5 inches
Minimum Span	9 mv or 0-300°F - Type J
Calibrated Accuracy	± 1% of full scale
Sensitivity	90 microamps for full scale deflection (nominal)
Internal Resistance	11 ohms per millivolt (nominal)
External Resistance	Calibrated for 15 ohms and supplied with replaceable compensator to make up difference between calibrated resistance and actual value of external resistance
Compensation	a) Automatic cold junction temperature compensation. Range 40 to 130°F b) Copper coefficient compensation. Range 40 to 130°F
Thermocouple Break Protection	TCB furnished
Control Output	Direct current
Control Output Span	2 to 12 milliamperes, into 1500 ohm load
Proportional Band	Adjustable from 0.5% to 4% of full scale
Control Adjustment	External control set point knob adjustable over 100% of scale. Reset control internally adjustable
Power Requirements	9 volt amperes

Power Supply	Interchangeable; 120 and 240 volts a-c, 50-60 cycle
Dimensions and Weights	
Overall Dimensions	6 7/8" wide x 6 1/4" high x 9 5/8" deep
Cutout for Flush Mounting	6 1/8" wide x 5 9/16" high
	NOTE: Meter housing will extend approximately 8" from back of panel when flush mounted
Net Weight	9 pounds
Shipping Weight	12 pounds

MATERIAL WARRANTY

All equipment except tubes, photocells, and thermocouples, which within one year from date of shipment is found to have been originally defective, will be repaired (replaced if necessary) free of charge, if returned immediately, prepaid, to the factory at Rockford, Illinois.

DESCRIPTION

General Description

The Model 277P Capacitrol is a millivoltmeter-type indicating controller with a d-c current output for proportional control of an intermediate or final control device. It is used as the primary control instrument for driving magnetic amplifier/reactor systems or silicon controlled rectifier power controllers for the proportional control of load power.

Control Specifications

The Model 277P Controller has a proportional direct current output of 2 to 12 milliamperes and is designed to be used with a 1500 ohm load. Two adjustments, "Reset" and "Proportional Band" are adjustable from the front of the instrument. Their operation is described under "Control Adjustments". The proportional band is adjustable from 0.5% to 4% of full scale. Proportional control action occurs when the meter indicator is within the proportional band range of the instrument, with its position on the scale determined by the control set pointer. After the controlled load has become thermally stable, any offset between the meter indicator and the control set pointer can be corrected with the reset adjustment as described under "Control Adjustments".

The control point can be easily adjusted through the full length of the instrument scale by means of a knob located just below the scale. The red signal light indicates when power is applied to the chassis. The output is from terminals 1 and 3, with terminal 1 of positive polarity and terminal 3 negative.

Description of Electronic Circuit

The Model 277P incorporates a transistorized oscillator and d-c amplifier, with the d-c output of the amplifier controlling an external power controller which, in turn, controls the load power. At a position on the scale below control point, the collector current of the oscillator transistor is of sufficient magnitude so the output of the d-c amplifier is greater than 12 milliamperes. As the indicator approaches control set point, a small vane or flag suspended from the indicating pointer passes between two flat coils mounted on the control set point arm. As the flag moves upscale between the coils, the collector current of the oscillator transistor is reduced. With the flag fully between the coils, the collector current is decreased to a minimum so that the output of the d-c amplifier is less than 2 milliamperes. Proportional control action occurs when the flag traverses a fixed distance between the coils, as discussed under "Proportional Control". In the 277P the input to the d-c amplifier is proportional to the oscillator collector current, con-

trolling the amplifier output. The proportional band is made larger or smaller by adjusting the level of feedback from the d-c amplifier to the oscillator, which regulates the oscillator collector current change with respect to flag movement. When there is no feedback the proportional band is at minimum, or 0.5% of full scale, and at maximum feedback the proportional band is increased to 4% of full scale or greater.

Proportional Control

Proportional control action provides a continuous linear relationship between the value of the measured variable and the position of the final control element. Overshoot and undershoot are reduced and close tolerance control is maintained. As stated above, proportional control of the d-c output current occurs when the flag is between the coils, and its position in the coils automatically determines the output of the instrument in d-c milliamperes to an external power controller. The external power controller (or magnetic amplifier) is generally set up so that a 12 milliampere input from the 277P will result in maximum power applied to the load, and a 2 milliampere input will produce a minimum (or zero) power to the load. A means of controlling load power is therefore obtained. After the meter indicator has reached the proportional band (with the flag between the coils) and moves upscale toward the control set point, the d-c milliampere output of the instrument decreases. At control set point the output would be approximately 7 milliamperes.

Figure 1 is an example showing the proportional band (PB) curves for a 4% setting and a 0.5% setting of a meter with a scale range of 0-1000°F. The 4% PB setting is obtained by turning the PB adjustment fully clockwise. Also, in Figure 1 are the 621 and 622 Series and Model 610A power transfer curves. The power transfer curves also assume that the input control winding resistance of the 610A and 621 and 622 Series is 1500 ohms. The curves give a relative indication of power output. For example, with a voltmeter attached to the test jacks and the meter reading 12 volts (8 ma with 1500 ohm load), the 621 and 622 Series power output would be 60% of maximum output power. If a Model 610A is used, the output of the 610A would be about 42.5 volts d-c, which would be the input to a reactor used in conjunction with the 610A magnetic amplifier.

As shown in the example, the meter would indicate about 596°F which would mean an offset of 4°F from control set point. This offset is corrected using the reset adjustment as described under "Control Adjustments". The example shows the proper reset adjustment for the particular control point selected. In this example, the power transfer

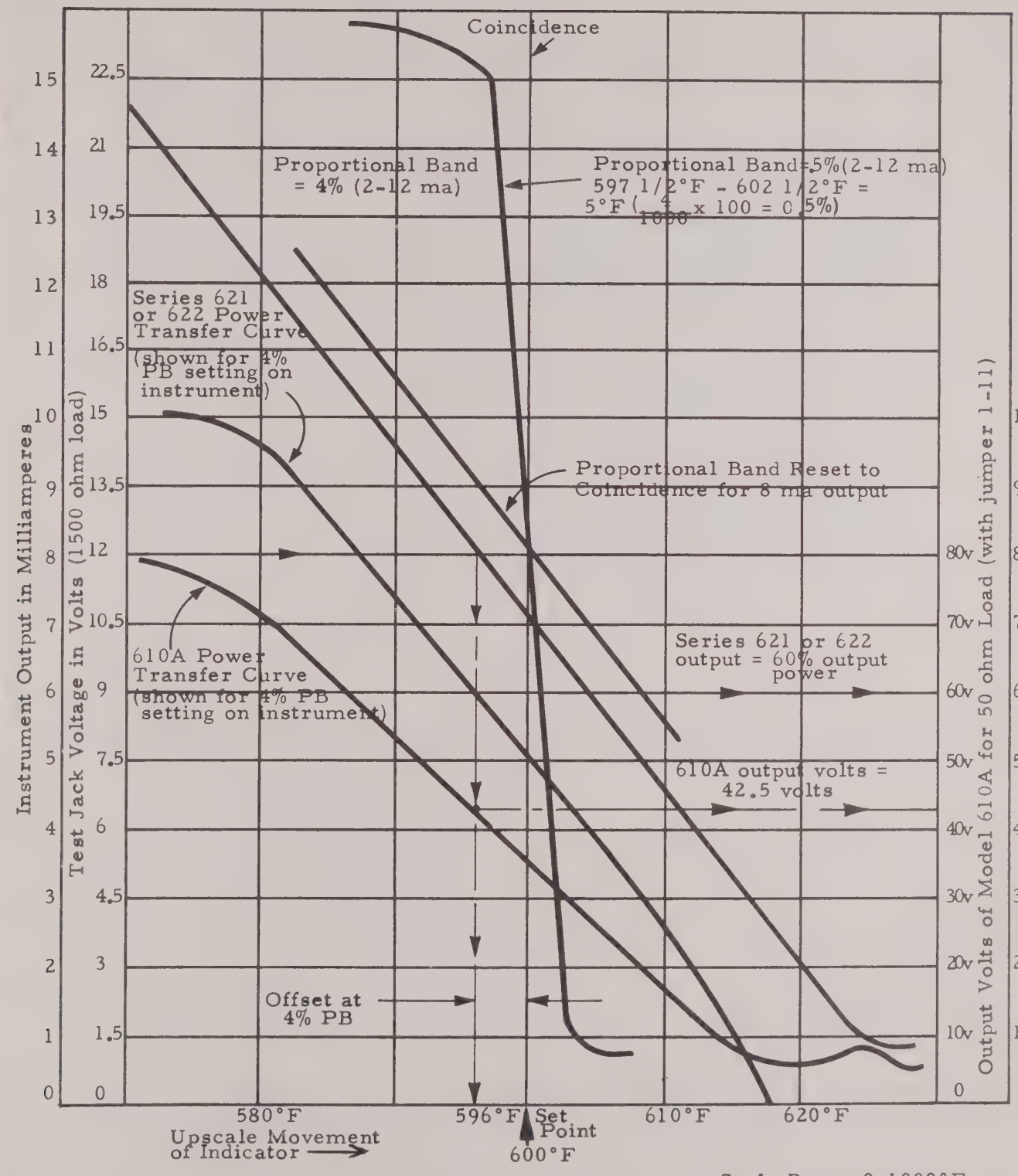

Coincidence
Proportional Band = 4% (2-12 ma)
Proportional Band=5%(2-12 ma)
597 1/2°F - 602 1/2°F =
5°F (5/1000 x 100 = 0.5%)
Series 621 or 622 Power Transfer Curve (shown for 4% PB setting on instrument)
Proportional Band Reset to Coincidence for 8 ma output
610A Power Transfer Curve (shown for 4% PB setting on instrument)
Series 621 or 622 output = 60% output power
610A output volts = 42.5 volts
Offset at 4% PB
Instrument Output in Milliamperes
Test Jack Voltage in Volts (1500 ohm load)
Output Volts of Model 610A for 50 ohm Load (with jumper 1-11)
% Output Power - 621 or 622 Series - 2 ma Suppression
580°F
596°F Set Point
610°F
620°F
Upscale Movement of Indicator
600°F
Scale Range 0-1000°F

Figure 1

Example of Proportional Control Action
as the Meter Indicator Moves Upscale
Through the Proportional Band of a 0-1000°F Meter

curves would also be shifted over the same amount as the proportional band curve.

In using the 277P in control systems, the proportional control of load power is obtained by using the direct current output of the 277P to control a magnetic amplifier (Model 610A) reactor combination or a Series 620 "SCR" Power Controller. The external wiring diagrams, pages 7 through 11, show typical connections. If reactors are used to control load power, a shunting resistor should be connected directly across the reactor control winding terminals, as shown in the wiring diagrams, to protect the reactor control winding in case the control circuit is opened under load, inducing a high voltage in the control winding.

As can be seen in Figure 1, there is always a small output when using a 610A or magnetic amplifier to drive a reactor. This results in a small amount of power always being applied to the load, even when the output from the instrument is less than 2 milliamperes. Two power amplifiers are available to control reactors: The Model 610A - a magnetic amplifier, and the Model 630A - an SCR type amplifier with a d-c output. The specifications are as follows:

Model 610A	Excitation 120 v, 60 cycle; output - 5 - 75 v d-c, maximum power output to reactor control winding 3- 188 va. Used with reactors up to 30 kva rating.
Model 630A	Excitation 120 v, 60 cycle; output - 0- 80 v d-c, maximum power output to reactor control winding - 750 va. Used with reactors up to 130 kva rating.

INSTALLATION AND START-UP

Unpacking the Instrument

This precision instrument and its associated equipment have been carefully manufactured and packed at the Factory. Remove the instrument and accessories from the packing box and check items against the packing slip. If the equipment is found to be damaged in transit, report damages to the carrier immediately. Repack in oridinal packing box until ready for installation.

CAUTION: Handle with care.
Safeguard instrument from shock before and after installation.
Avoid oil accumulation and exposure to moisture.
Keep instrument temperature under 130°F and over 40°F.

Mounting Instructions

Locate instrument to avoid excessive vibration, shock, and temperatures outside the range of 40°F to 130°F. Avoid furnace walls, radiation of heat, machine frames, and outside walls. Provide suitable shelter against moisture and temperature extremes if installed outdoors. Refer to appropriate drawings, Figures 2 and 3, for mounting details.

Power Wiring

The unit is suitable for 120 v or 240 v, 50/60 cycles a-c, by choice of proper terminals on the back of the instrument housing. Solid wire (14 gauge) is suggested for power wiring. If stranded wire is used, tin the ends to provide secure connections.

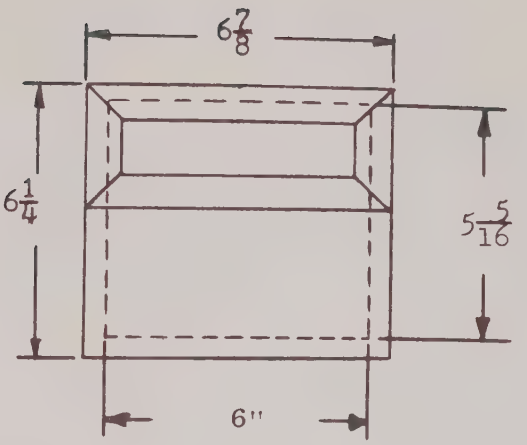
Wiring should be in accordance with applicable electrical codes. Where maximum protection of the instrument is desired, a "slow blow" 1/8 ampere fuse may be added in the power line to the instrument.

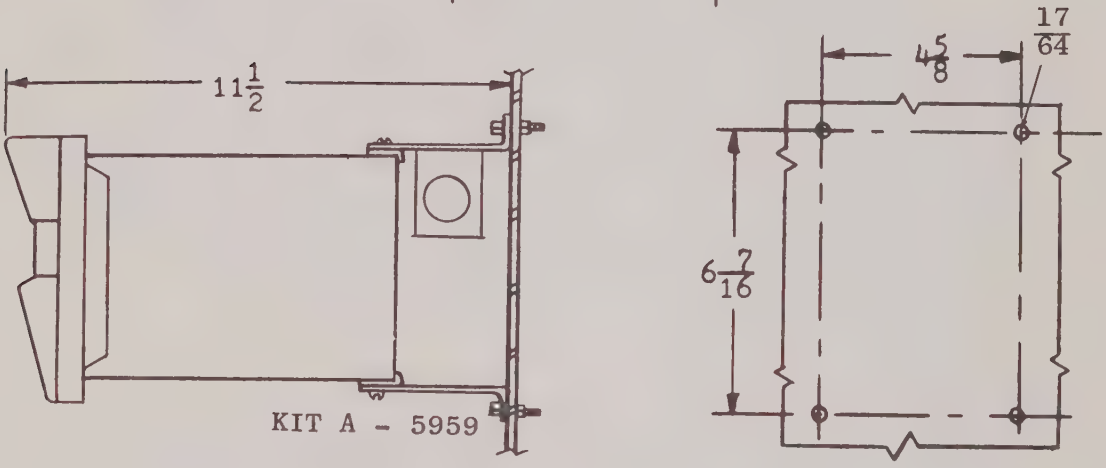
The instrument case should be grounded. This is accomplished by attaching the GRD terminal directly to a good ground, such as a cold water pipe.

CUATION: Do not connect the GRD terminal to the neutral a-c line.

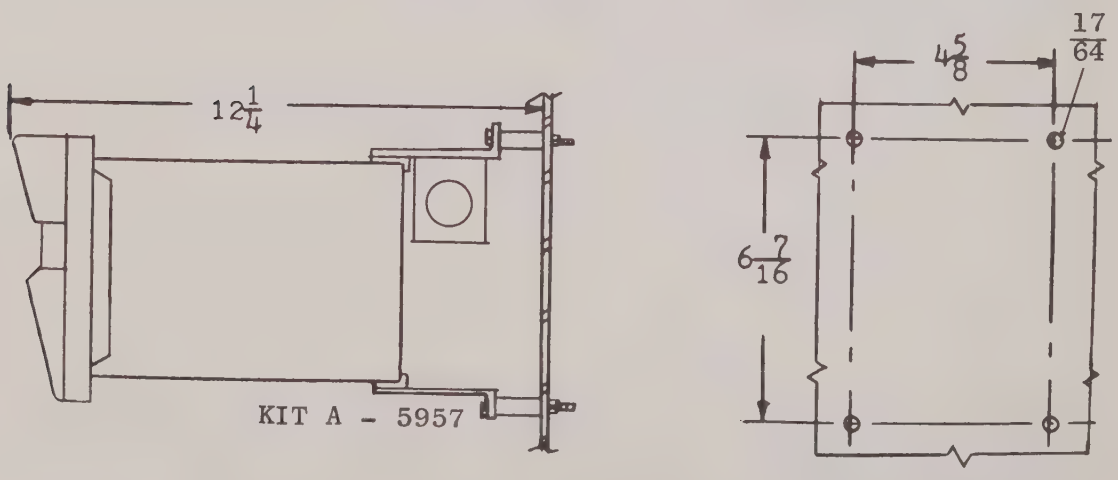
Terminals 1 and 3 are wired internally to the control chassis to obtain a d-c output current. Terminal 1 is the positive terminal, and terminal 3 is the terminal. The external wiring diagrams (Figures 3 through 8) show some typical wiring diagrams.

FRONT VIEW AND
CASE DIMENSIONS



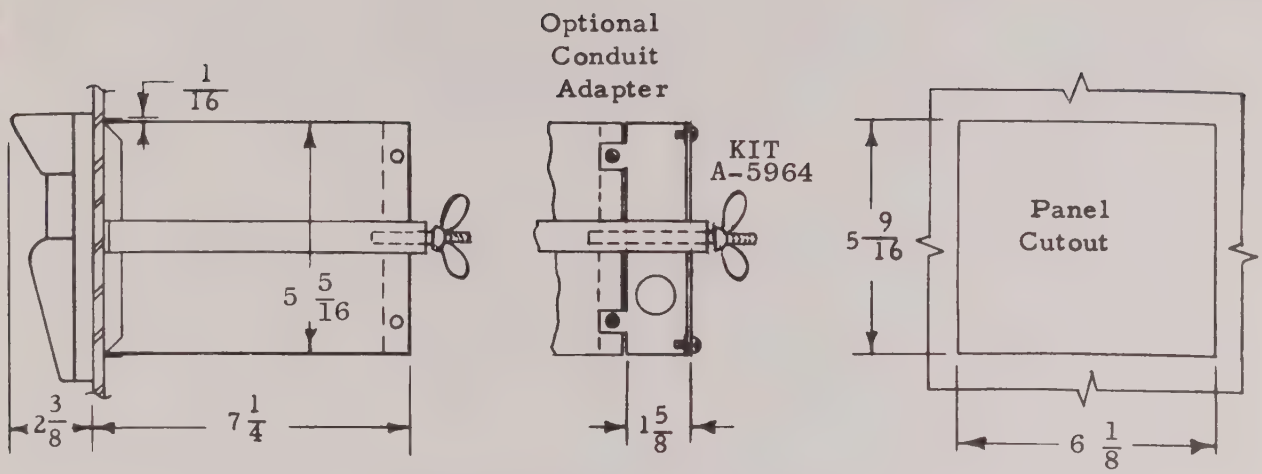


SURFACE MOUNTING DIMENSIONS

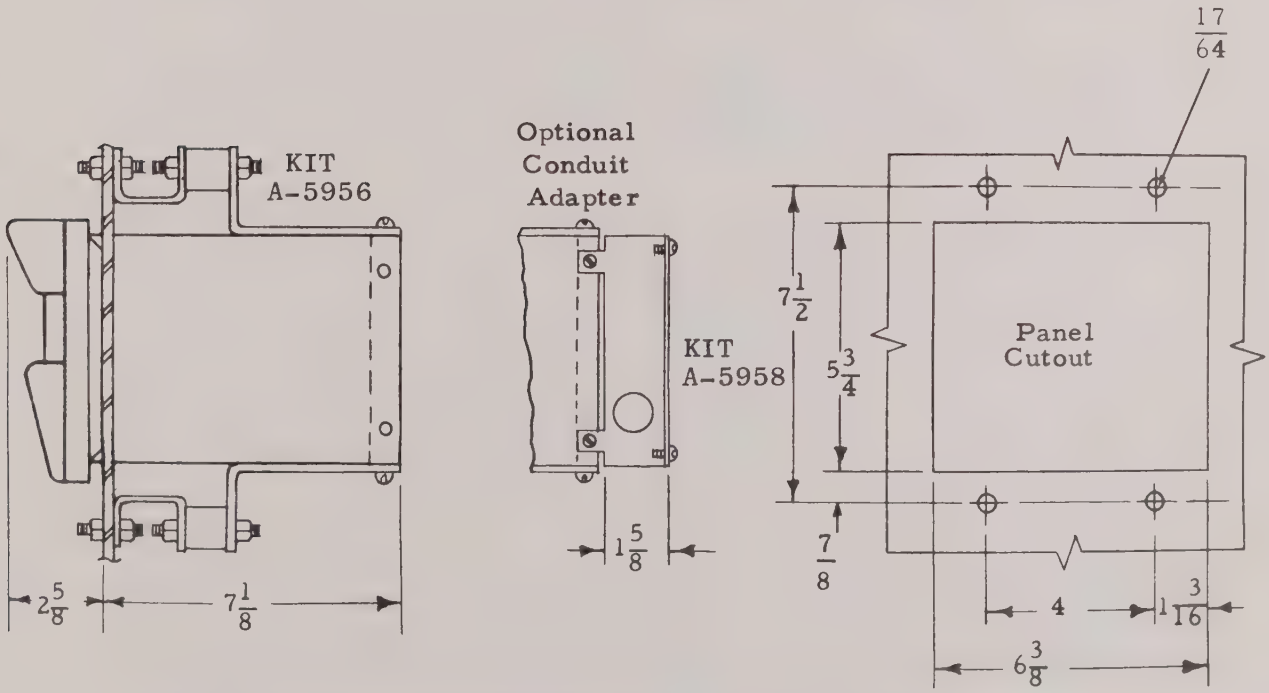


VIBRATION MOUNTING ARRANGEMENT FOR SURFACE MOUNTING

FIGURE 2



FLUSH MOUNTING DIMENSIONS



VIBRATION MOUNTING ARRANGEMENT FOR FLUSH MOUNTING

FIGURE 3

Meter Shunt Wire

After the instrument is installed, disconnect the jumper wire across terminals marked "Shunt" and "TC-". This wire is used to shunt or dampen the meter movement for protection during shipping, handling and installing the instrument, but should be removed for normal operation. Replace the shunt wire when handling or shipping the instrument and position the red control set pointer fully upscale.

Thermocouple Wiring

The single unit meter and chassis plug-in assembly has a thermocouple selection feature which should be checked to see that thermocouple connections are properly made. This is done by removing the instrument from its case and noting the pin connections on the small terminal board at the rear of the meter enclosure. The leadwire marked "A" should always be connected to pin "A" and the leadwire marked "B" should always be connected to pin "B". If a base metal thermocouple is used (Type J, T or K) the wire labeled "C" should be connected to the third pin, marked "C or D". If a noble metal thermocouple is used (Type R or S) the wire labeled "D" should be connected to this pin.

Do not run thermocouple leadwire with other power or control wiring. Leadwire may be run with thermocouple break (TCB) wires, however. Several thermocouple leadwires may be run in the same conduit if desired.

Use only extension leadwire correct for the type of thermocouple (TC) as specified on the scale. The types most commonly specified are: Iron-Constantan (Type J), Chromel-Alumel (Type K), Platinum-Platinum 10% Rhodium (Type S), Platinum-Platinum 13% Rhodium (Type R), and Heat-eye. Ordinary copper wire must not be used for these elements, although it can be used with Barber-Colman Land Radiation Pyrometers and certain other radiation detectors. See Barber-Colman Thermocouple Catalog for a full selection of thermocouple assemblies and extension leadwire.

Proper polarity (+) and (-) of the leadwire must be observed to obtain correct readings. The negative wire is usually coded red. Correct polarity of the leadwire can be checked by twisting the two wires together at the far end, heating this junction with a match, and noting the deflection of the meter indicator. An upscale deflection is proof of correct polarity of the leadwire.

The leadwire should then be connected to the thermocouple and the indicating pointer should again deflect upscale when the thermocouple hot junction is heated. If the indicator moves downscale, reverse only the leadwire connections at the thermocouple since the leadwire has already been correctly connected to the instrument.

Secure the leadwires firmly under the terminal screws. If desired spade lugs may be used.

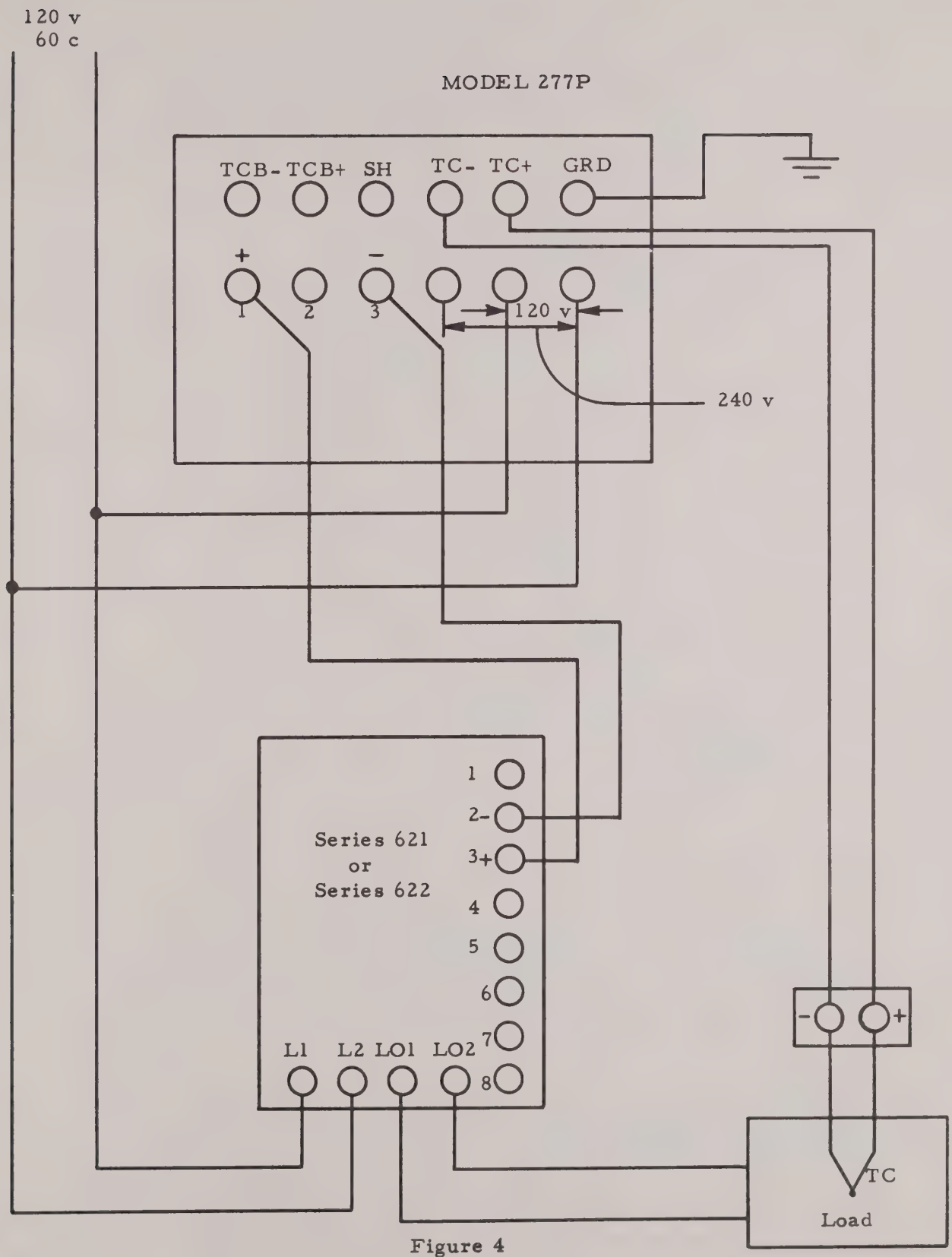
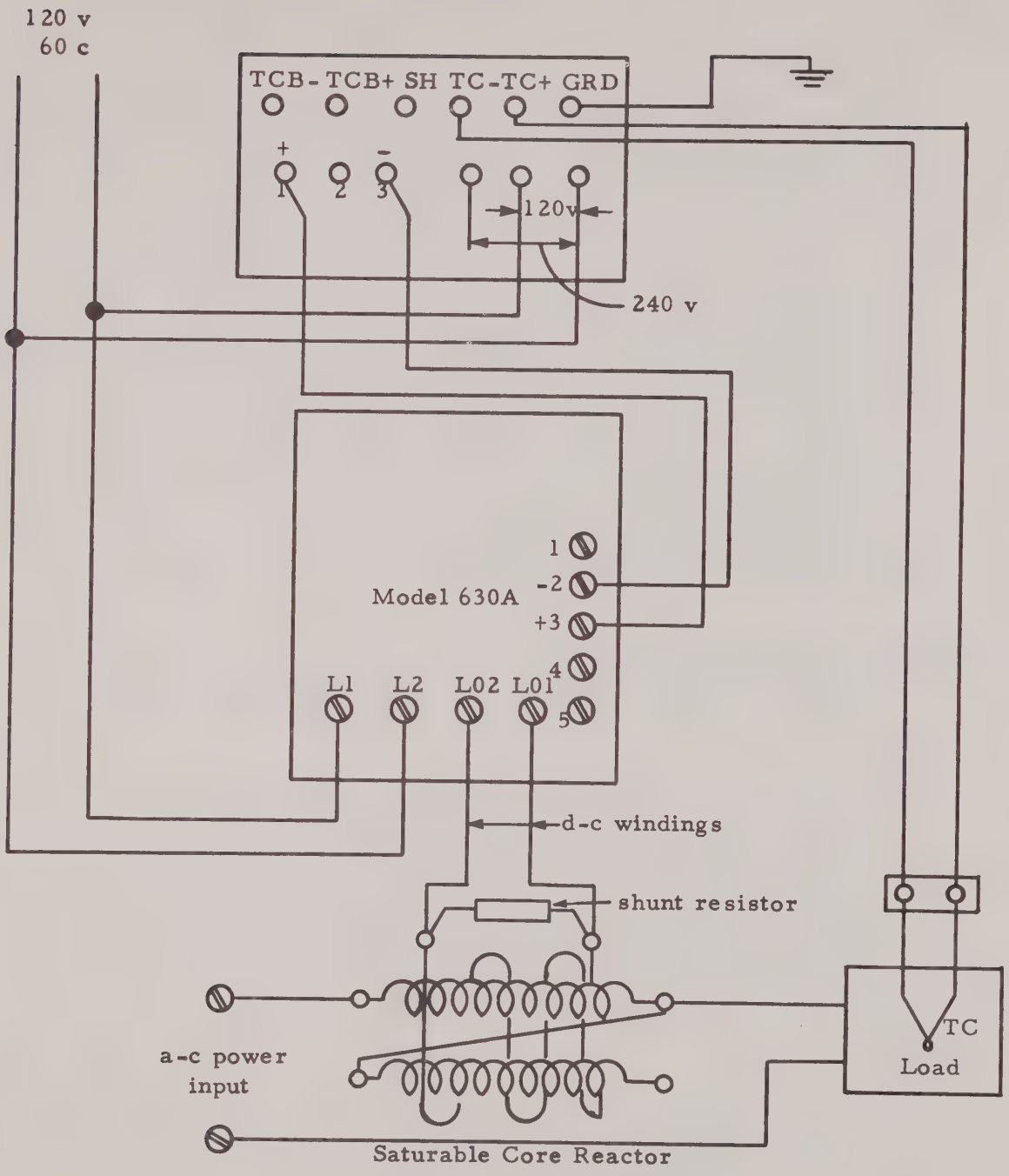


Figure 4

External Wiring Diagram of a Model 277P
Driving a Series 621 or 622 Power Controller



Reactor coils may be parallel connected for lower line voltage. Refer to manufacturer's specifications.
Identification of control winding terminals differ with various manufacturers.

Figure 5

External Wiring Diagram of a Model 277P
Driving a Saturable Core Reactor through a
Model 630A SCR Pilot Amplifier

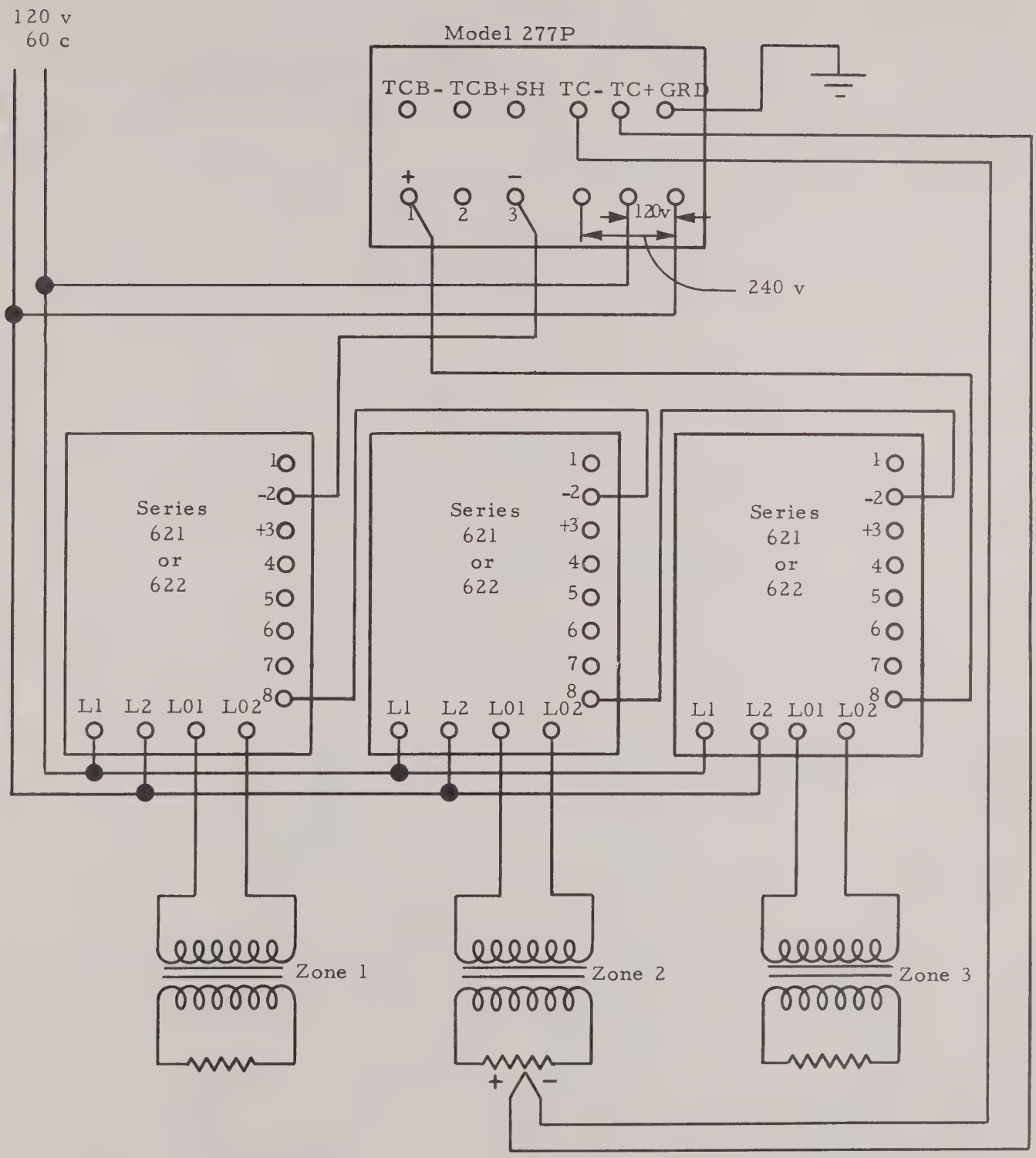


Figure 6
External Wiring Diagram of a Model 277P
Controlling Three Zones from a Central Zone
Using Series 621 or 622 Power Controllers

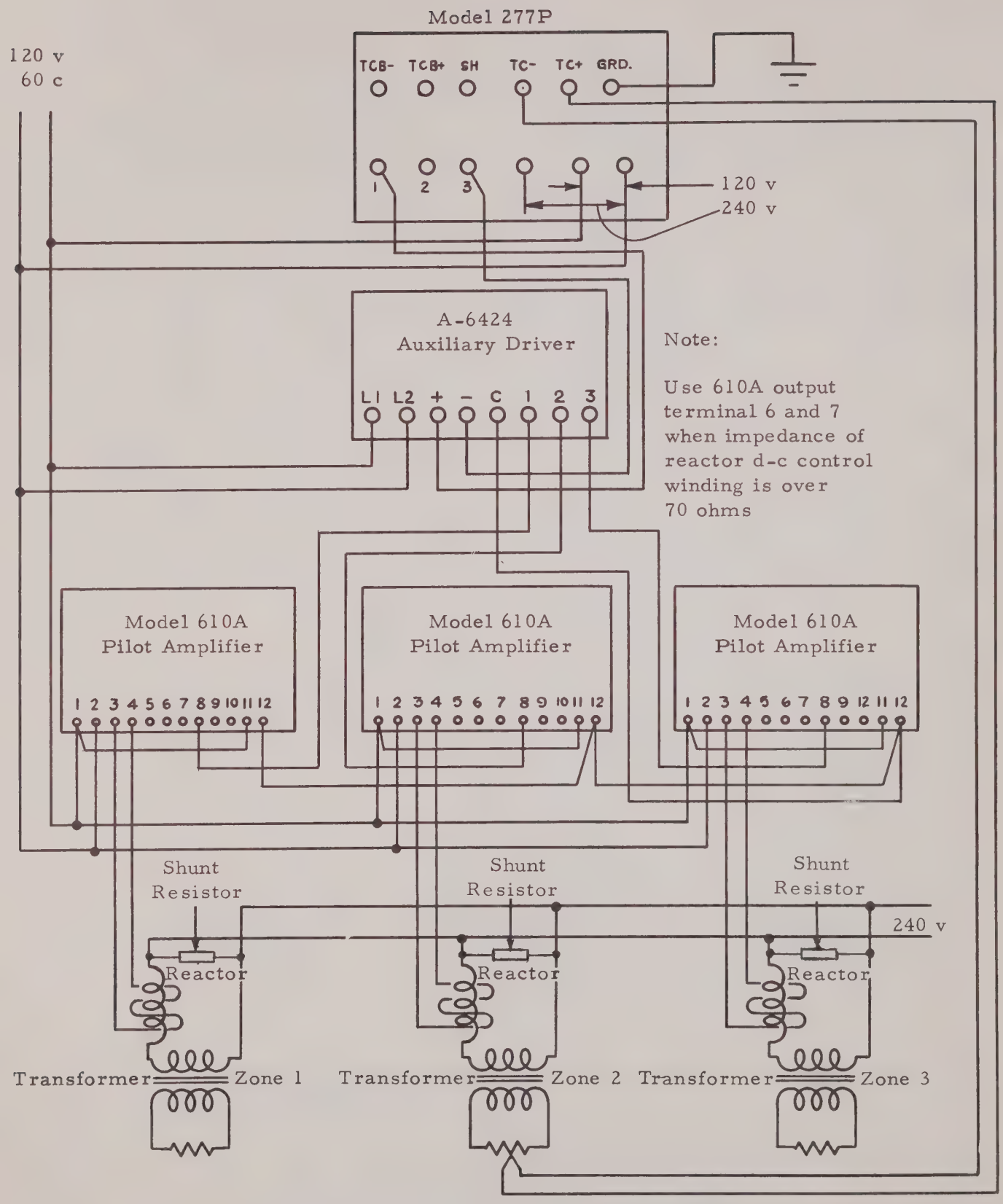
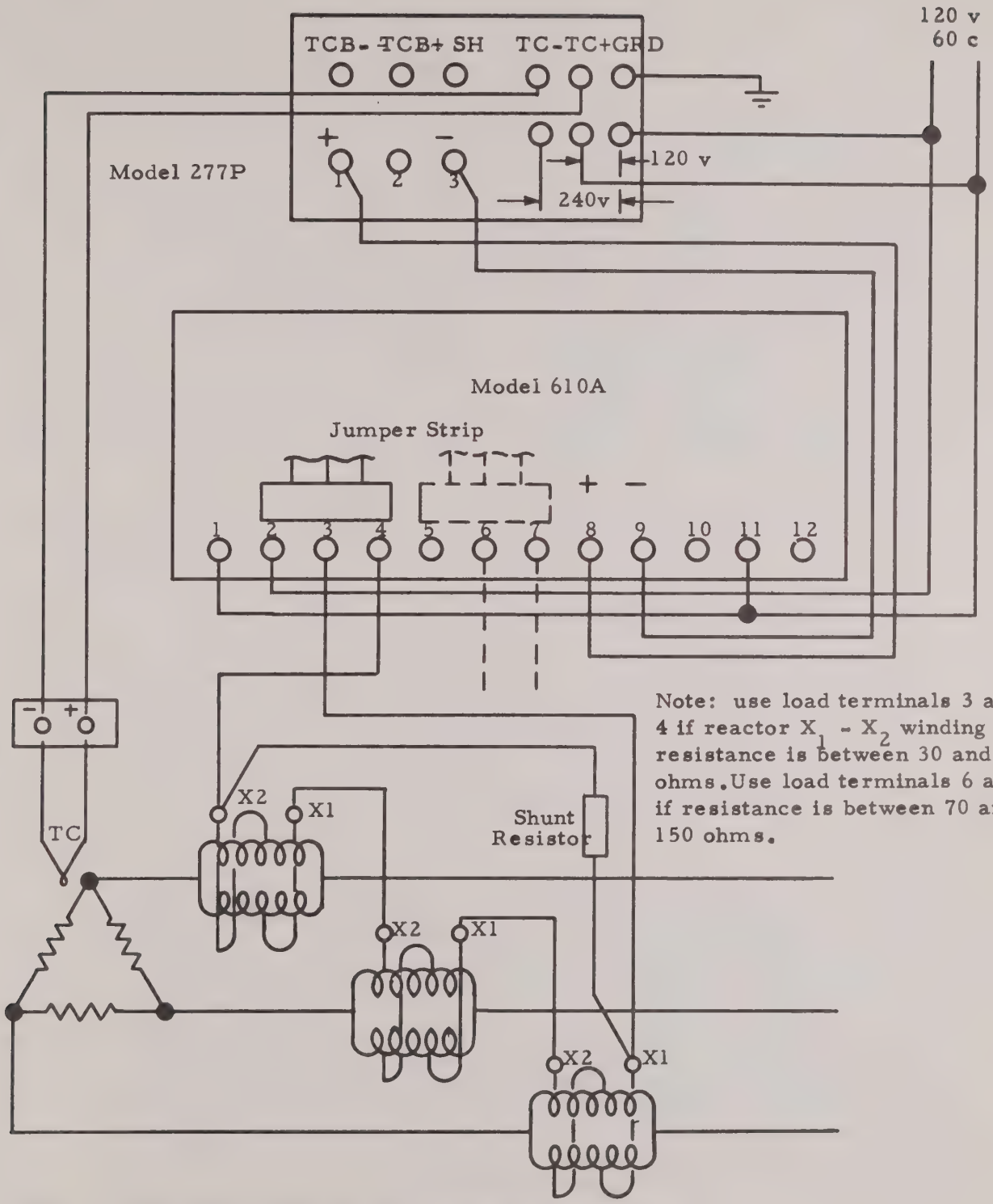


Figure 7
External Wiring Diagram of Model 277P Controlling Three Zones from a Central Zone using Saturable Reactors and Model 610A Pilot Amplifiers (note that an auxiliary driver is used for impedance matching)


TCB- TCB+ SH TC-TC+GRD
120 v
60 c
Model 277P
+ −
1 2 3
120 v
240v
Model 610A
Jumper Strip
+ −
1 2 3 4 5 6 7 8 9 10 11 12
Note: use load terminals 3 and 4 if reactor X1 - X2 winding resistance is between 30 and 70 ohms. Use load terminals 6 and 7 if resistance is between 70 and 150 ohms.
− +
TC
X2 X1
Shunt Resistor
X2 X1
X2 X1

Note: Three phase reactors may be individually shunted.
Reactor d-c coils may be parallel connected in special cases.
Refer to manufacturer's specification sheets accompanying reactor.

Figure 8

External Wiring Diagram of Model 277P Driving a Three-Phase Saturable Reactor Through a Model 610A Pilot Amplifier

Line Compensating Resistor

The external resistance, for which the meter has been calibrated and as marked on the scale, is the combined resistance of the extension leadwire and thermocouple. Meters are normally calibrated for 15 ohms (Ext.Res.15 ohms), which allows for more resistance than the average length of leadwire. The balance of the resistance, 15 ohms minus the actual external resistance, is supplied as a removable compensating resistance spool located on the negative TC terminal at the back of the instrument. The resistance value is marked on the spool which is attached at the time of the original order. Minor changes in the leadwire length can be made without appreciable error in reading because a high resistance movement is used.

Compensating resistors of other values can be obtained at nominal cost.

Thermocouple Break Protection (TCB)

The instrument is equipped with thermocouple break protection (TCB) to be used if desired. This protection is provided by a small d-c voltage superimposed onto the thermocouple circuit so that, in the event of a break in the thermocouple circuit, the meter movement will be driven upscale past the control set point where the output will be less than 2 milliamperes. The instrument will operate in a normal manner without TCB connected, but its use may be desired on some applications to guard against overheating in the event of an open thermocouple.

Methods of connecting TCB are shown in Figure 9. Use the required extension leadwire to make the connections between the instrument terminals and the thermocouple head. Copper wire, 16 to 20 gauge, is generally used to connect the TCB terminals to the thermocouple head, observing polarity. Wiring for TCB may be run in the same conduit with thermocouple leadwire. Although not recommended, an optional method of connecting TCB is to use jumpers at the instrument terminals with short leadwire lengths (10 feet or less). When using longer lengths of leadwire, this method may result in a noticeable error in the meter reading. The amount of TCB error must then be determined. (See section on Meter Adjustments.

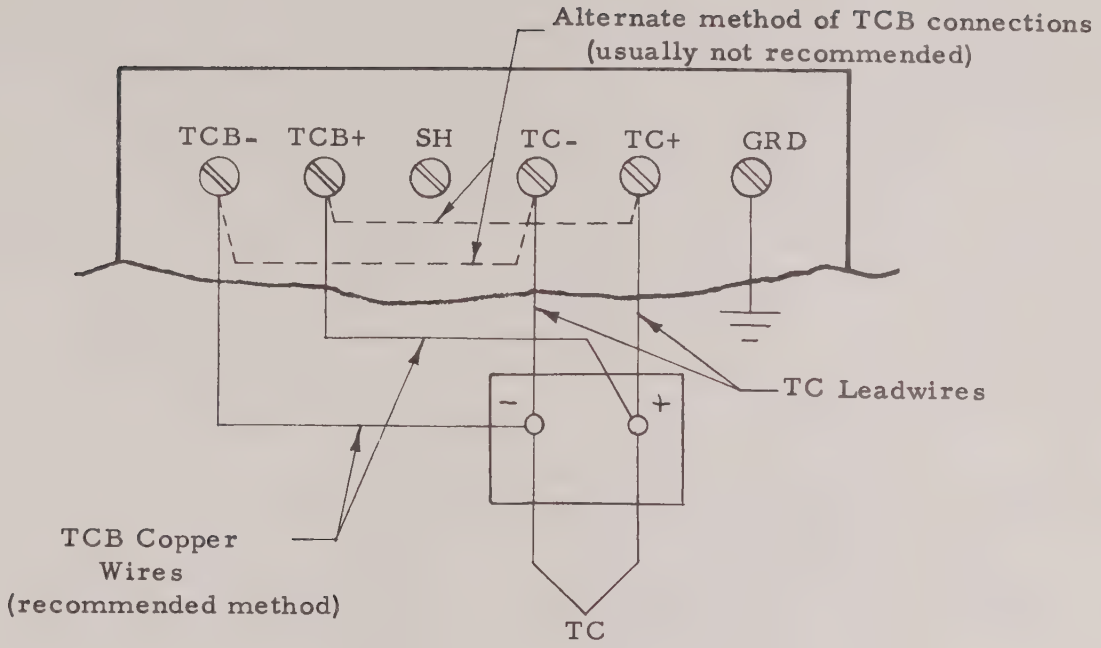


Figure 9

TCB WIRING METHODS

To check for correct TCB operation, disconnect the thermocouple to simulate a broken thermocouple but leave the TCB wires connected. When the instrument is powered, TCB is functioning properly if the indicator is driven upscale above the red control set pointer to cause the output of the control chassis to decrease to less than 2 milliamperes.

TCB is not effective on radiation detectors because of the compensating network in those devices. Do not connect TCB when the instrument is used in conjunction with a Series 350 Reference Voltage Source. See Series 350 Instruction Manual for complete instructions.

1211.8 IN 4

OPERATION

Removing Instrument from Housing

The meter and chassis comprise a single-unit assembly with connections to plug into the rear terminal board inside the housing. For servicing or interchange of control forms, the complete unit is removed from the housing by completely loosening the two screws on the front face and pulling forward firmly. Do not attempt to pry the unit apart from the housing.

Meter Adjustments

Cold Junction Compensation:

For measuring temperature, thermocouples are the most commonly used sensing devices. They produce a voltage when there is a temperature difference between the "hot" or measuring junction and the "cold" junction located in the meter assembly. Since the difference in temperature between the hot and cold junctions determines the amount of millivoltage produced, it is necessary to keep the cold junction temperature constant, or to compensate for any changes that occur at this point. The Series 270 instruments compensate for temperature changes at the cold junction through the use of a bimetallic strip. After properly adjusting for ambient temperature, further correction for ambient temperature changes need not be made.

After the instrument has been mounted, and before it has been powered, disconnect the thermocouple at one of the terminals and read the temperature indicated on the scale. The indicator should not read zero, but should come to rest at the ambient temperature. Use a reliable mercury thermometer to determine the correct ambient temperature. (If instrument is mounted in a panel, measure the temperature inside the panel and allow enough time for the instrument to reach inside panel temperature). If the pointer does not read ambient, slowly adjust the screw located on top of the meter cover until it does.

If a check of cold junction compensation is to be made after a period of operation, heat rise within the instrument housing must be allowed for. Because the rate of heat dissipation depends upon the environment, the heat rise will not be a constant, but will usually vary between 5° to 10° above the external temperature. Where close measurement accuracy is desired, a small thermometer should be placed inside the housing on top the chassis with the bulb near the meter thermocouple selection terminals. After allowing time for the inside temperature to stabilize, an adjustment should be made to set the meter indicator to the thermometer reading.

TCB Compensation:

It is necessary to compensate for TCB only if the meter tends to read significantly high when the instrument is powered. Should it be desired to compensate for this upscale deflection, the reading may be shifted downscale as explained below:

With the instrument previously adjusted for correct ambient temperature, the thermocouple should be held at a steady temperature while observing the difference in meter readings with the unit powered and unpowered. If the difference is discernable, compensation may be made with the ambient temperature adjusting screw. With the instrument powered, turn the screw to lower the indicated reading to the same point on the scale as observed when the power was off. The cold junction or ambient adjustment is thereby also changed downscale. An alternate method of making this check is by making and breaking the TCB circuit.

Control Adjustments

Final control adjustments should not be made until after the unit has been in operation 45 minutes and has obtained maximum stability. The controls are accessible by removing the front access cover, which is removed by pulling the small knob located below the control set point knob.

Proportional Band Adjustment:

The proportional band (PB) adjustment is used to vary the proportional band from 0.5% to 4% of full scale. Turning the PB adjustment clockwise will increase the PB, and counterclockwise will decrease it. The ideal PB setting is at its furthest counterclockwise or minimum adjustment which will permit straight line control. This setting is best obtained in the following manner:

1. Set the PB adjustment fully clockwise (maximum PB) and apply power to the controlled load.

2. When the controlled load temperature has become thermally stable at or near control set point, reduce the PB by turning the adjustment counterclockwise one graduation on the dial. To simulate a control upset, also move the control set point a few divisions. Allow time for the process to reach the new control point setting and then

observe if there is a cyclic variation. This would appear as an up and downscale movement of the indicator pointer.

3. If cycling is not present, repeat Step 2 until cycling occurs.

4. From the setting where cycling is continuous, increase the PB by turning clockwise one graudation. Again change control set point and allow time for load temperature to stabilize. At this point, cycling should have disappeared and straight line control established.

With proportional band properly set, response time of the instrument (sensitivity to load changes) is optimized, and the control offset is also reduced.

Reset:

A "reset" adjustment (the slotted shaft) is located on the left front of the control chassis, accessible by removing the lower compartment cover.

Reset adjustment provides a means of aligning the meter indicator with the control set pointer to correct for offset. If the meter indicator does not coincide with the control set pointer after the controlled load has become thermally stable, an alignment adjustment should be made. Use a small screwdriver to reposition the reset adjustment capacitor. Turning the reset adjustment counterclockwise will decrease the output of the instrument, thereby shifting the meter downscale so as to produce a lower temperature. Conversely, turning the reset adjustment clockwise will result in shifting the meter indicator upscale, producing a greater temperature. The reset adjustment should be in small increments with sufficient time allowed after each adjustment to permit the controlled load to again become thermally stable. The proper reset adjustment occurs when the meter indicator coincides with the control set pointer when the load is thermally stable.

For a discussion of proportional control and reset, see pages 2, 3 and 4.

1211.8 IN 4

Routine Servicing

The 277P instrument is well designed and manufactured of high grade components and with normal care will give uninterrupted service for a long time. It is good practice, however, to have information as to service and spare parts for emergency servicing. Where a number of instruments of this series are located together, the single unit meter and chassis plug-in assemblies are interchangeable to allow minimum inventory.

When trouble is encountered, the service man should familiarize himself with the process and instrument application to determine the exact function of the instrument as applied. The instrument trouble usually can be traced to two basic problems: measurement or control.

Measurement and Control Trouble

Measurement trouble can be detected by observing the pointer position. If the measured temperature is known to be in error, check the following:

(1) Open or broken thermocouple, leadwire or connector.

(2) Deteriorated thermocouple. Compare reading with a test thermocouple.

(3) Check to see that the capacitor is properly connected between the thermocouple input terminal and the ground terminal inside the back panel of the meter-chassis unit. Also ascertain that the instrument is properly grounded.

(4) Accidental shorts, grounds or moisture in the leadwire (especially with asbestos type insulation).

(5) High resistance in leads due to loose connectors, poor splicing, dirty switch contacts, and other faulty connectors.

(6) Problems caused by vibration or shock.

(7) Meter accuracy. This can be checked with a Barber-Colman Portable Potentiometer.

(8) Errors due to oil and grease. Do not oil or grease any part of the instrument.

(9) Incorrect cold junction (ambient) setting. The correctness of this setting should be checked following any other meter servicing. See page 17.

Control trouble may be detected by observing control point and indicator pointer position. If control action does not occur at control point, do the following:

(1) Check electrical connectors and correctness of line voltage. Ascertain as to whether trouble is internal or external to the instrument.

(2) Determine if instrument, magnetic amplifier or power controller are powered; check load power for open circuits and open legs in three-phase circuits.

(3) Check the supply voltage to the components. It should be within ± 10% of rated line voltage. Excessive line voltage variations can cause large fluctuations in load power.

(4) Check to see if the reactor rating is compatible with the load rating.

(5) Check the output of the Model 277P by connecting a d-c voltmeter to the instrument's test terminals to measure the instrument's output. When the black indicator is well to the left of the control set point the meter reading should be greater than 18 volts d-c. When the black indicator is well to the right of the control set point, test meter should read 3 volts d-c or less.

(6) If the instrument output is low (less than 18 volts d-c) when the indicator is considerably to the left of the set point, check for improper reset adjustment.

(7) If there is no power applied to the load with the instrument energized, attach a d-c voltmeter to the test jacks. If the voltmeter indicates zero output, make sure the meter indicator is well to the left of the set point and then turn the reset adjustment through its entire adjusting range. If the d-c voltmeter then indicates an output to the controller, let the controlled load stabilize and then make an adjustment of reset as described under "Control Adjustments". If the instrument does not then function, further servicing or replacement of the control chassis is suggested.

Calibration Check

The instrument has been calibrated at the factory to the specified limits of accuracy. Under ordinary circumstances, no further adjustments need be made. If, however, it is later decided to check the calibration, connect a Barber-Colman Portable Potentiometer (or equivalent) to the thermocouple terminals and follow the steps as outlined in the portable potentiometer instruction manual.

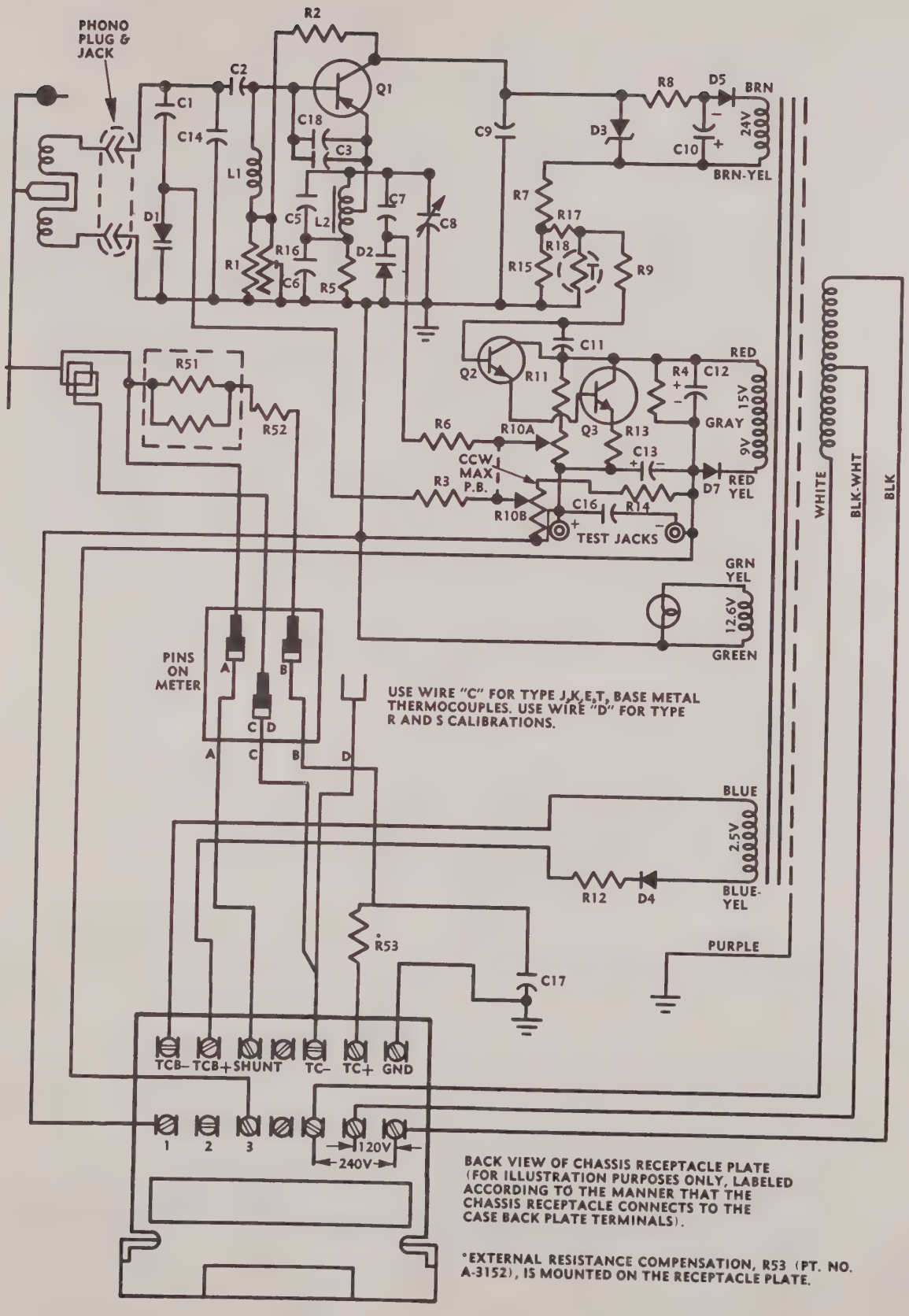
An alternative method of making connections to the portable potentiometer is to remove the instrument from its case and place it on a level surface. The leads from the portable potentiometer may then be attached to pins "B" and "C" (pin "B" is positive) on the thermocouple selection board. After setting the external resistance for 15 ohms, the usual calibration procedure is followed.

SUGGESTED REPLACEMENT PARTS TO KEEP ON HAND

Quantity	Part Description	Part Number
2	MAZDA Pilot Lamps	30-164
1	Replacement Thermocouple (Refer to Thermocouple Catalogs - DB 1111-1a or DB 1111-2)	
1	Control Chassis	A-6386
	or	
	Single Unit Meter-Chassis Assembly	A-6396

We do not recommend electronic component replacement except by well equipped instrument repair shops.

Barber-Colman, Industrial Instruments Division, maintains service and repair facilities in many major cities in the United States and Canada. Consult your yellow page directory.



BACK VIEW OF CHASSIS RECEPTACLE PLATE (FOR ILLUSTRATION PURPOSES ONLY, LABELED ACCORDING TO THE MANNER THAT THE CHASSIS RECEPTACLE CONNECTS TO THE CASE BACK PLATE TERMINALS).

*EXTERNAL RESISTANCE COMPENSATION, R53 (PT. NO. A-3152), IS MOUNTED ON THE RECEPTACLE PLATE.

MODEL 277P - INTERNAL WIRING DIAGRAM

PARTS LIST

Item	Part Number	Description
C1, C7	39-69	Capacitor 100 μμf
C2, C6	39-76	Capacitor 250 μμf
C3, C14	39-212	Capacitor 8 μμf
C5	39-80	Capacitor 47 μμf
C8	39-160-1	Capacitor 2.9-35 μμf
C9, C16	39-103	Capacitor .01 μf
C10, C12, C13	39-153	Capacitor 50 μf
C11	39-228	Capacitor .47 μf
C17	39-98	Capacitor 1 μf
C18	39-155	Capacitor 10 μμf
D1, D2	37-60	Variable Capacitor Diode
D3	37-93	Zener Diode
D4	37-30	Silicon Diode
D5, D7	EYZP-384	Silicon Diode
L1	41-133	Choke 22 μh
L2	41-130	Coil 1.2 μh
Q1	31-50	Transistor (2N2188)
Q2, Q3	31-69	Transistor (2N696)
R1, R8	CYZR-133-2	Resistor 1.5 k Ω
R2	40-82	Resistor 33 k Ω
R3, R6	CYZR-170-18	Resistor 4.7 meg Ω
R4	CYZR-170-58	Resistor 10 k Ω
R5	40-77	Resistor 270 Ω
R7	CYZR-170-47	Resistor 330 Ω
R9, R17	CYZR-170-25	Resistor 3.9 k Ω
R10A, R10B	29-148	Dual Pots 100 k Ω
R11, R14	40-70-2	Resistor 47 k Ω
R12	CYZR-170-38	Resistor 5.6 k Ω
R13	40-78	Resistor 15 Ω
R15	CYZR-170-36	Resistor 680 Ω
R16	BYZR-147-1	Resistor 15 k Ω
R18	CYZR-676	Thermistor
R51	A-3049-1	Temperature Compensator
R52	A-1847	Calibrating Resistor
	30-164	Transformer
	36-34	Pilot Bulb

DEFINITION OF TERMS

CONTROL SET POINT	The position on the instrument scale to which the control point setting mechanism is set.
CONTROLLED VARIABLE	That quantity or condition which is varied by the controller so as to affect the power of the measured variable. Example: Power to an electric furnace.
CYCLING	A periodic change of the measured variable from one value to another. Oscillation and hunting are synonymous terms.
FINAL CONTROL ELEMENT	That portion of a control system which directly changes the value of the controlled variable. Example: Model 621A Power Controller.
MEASURED VARIABLE	That quantity or condition which is measured and regulated through control of the controlled variable. Example: Temperature in a furnace.
OFFSET	A sustained deviation from control point due to proportional control action. It is the difference existing at any time between control point and the actual value of the measured variable. Droop is a synonymous term.
OSCILLATION	See Cycling.
PROPORTIONAL BAND	That change in value of the measured variable that is necessary to cause full travel of the final control element. It is measured as a percent of full scale span. Throttling range is a synonymous term.
PROPORTIONAL CONTROL	Controller action in which there is a continuous linear relation between the value of the measured variable and the position of the final control element. In other words, the output of the controller is proportional to its input. Synonymous terms are throttling or modulating action.

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